§10. Difference of the ECRH Efficiency for Different Transverse Distance in the Ergodic Layer

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It has been derived that the electron cyclotron resonance heating (ECRH) efficiency of the 77GHz electron cyclotron (EC) wave tends to be less than 30% that of 154 GHz EC wave estimated in the same way for the same target plasma even if the ray-tracing calculation suggests 100 % power absorption in both cases. Recently we have obtained helpful experimental results to consider this problem when the 77GHz EC wave was launched toward the second harmonic electron cyclotron resonance (ECR) layer from a horizontal port antenna at various toroidal injection angles as a right hand circular polarized (R-circ.) wave as shown Fig.1-(A). Substantial reduce of the ECRH efficiency was observed in the injection case of (d) as shown in Fig.1-(B). The extraordinary mode fraction of the R-circ. wave estimated with assuming that the vacuum/plasma interface is located at the last closed flux surface (LCFS) is more than 95% for all cases except for the case of (C). Actually as shown in Fig.2, the plasma electron density exists even outside the position of the a_{99} minor radius that can be assumed as the LCFS for convenience. However, the change of the polarization of the X-mode taking into account of the outward shift of the vacuum/plasma interface is negligible and cannot explain the reducing of the ECRH efficiency.

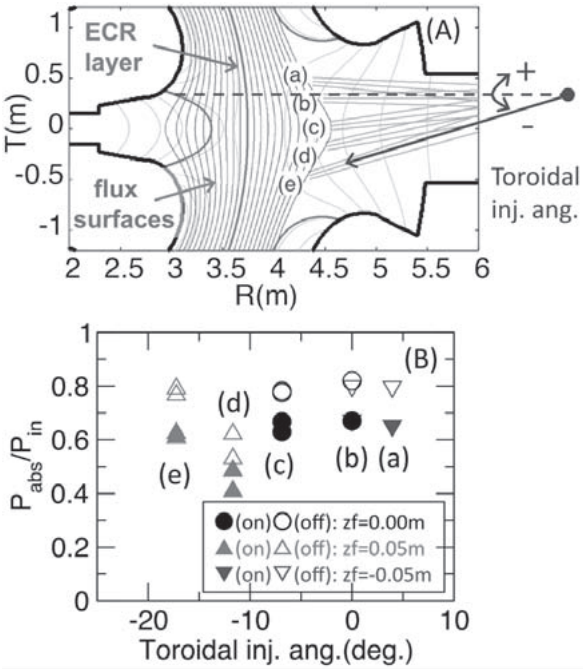

Fig. 1: (A) Schematic view of the EC wave injection from the horizontal port antenna. (B) ECRH efficiencies plotted versus the toroidal injection angle. Here, 'zf' is the vertial distance of the aiming point from the equatrial plane at R=3.9m.

As a possible reason, the effect of the mode coupling between the O-mode and the X-mode caused in the low density region where the difference between the refractive indices of the O- and the X-mode is small can be pointed out. If the typical length for the gradients is less than that for the anisotropy in the low density region with magnetic shear, the mode coupling occurs and the characteristic modes lose their identities. Comparing with the low efficiency case (d) shown in Fig.3 and high efficiency case (e) shown in Fig.4, the transverse distance in the ergodic layer is longer in the case (d) than the case (e). It can be speculated that in the low efficiency case (d), the transverse distance in the low density region with magnetic shear where the mode coupling takes place is long enough that the fraction of the injected power that finally couples with the X-mode that reaches the second harmonic ECR layer reduces.

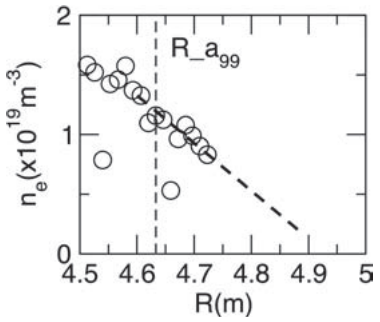

Fig.2: Profile of the electron density on the equatorial plane obtained by Thomson scattering measurement. R_a_{99} means the position of the a_{99} minor radius inside that 99% of the electron kinetic energy is included.

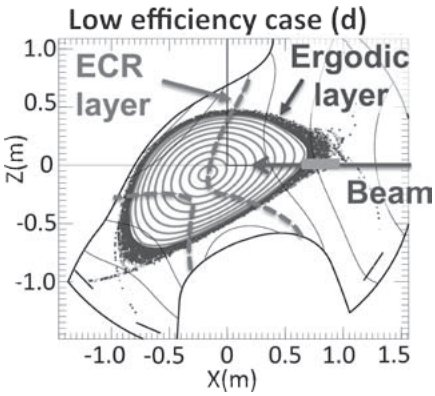

Fig. 3: Cross-section view of the plasma along the incident beam for the case of injection (d).

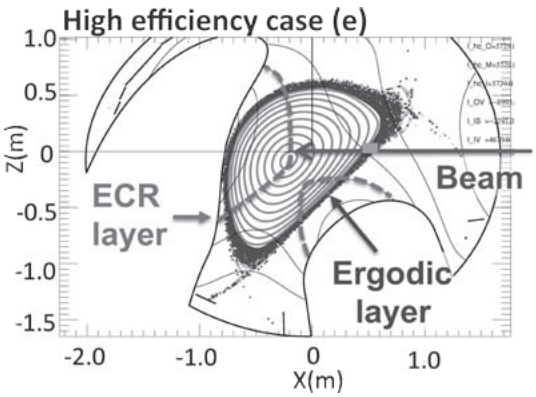

Fig. 4 : Cross-section view of the plasma along the incident beam for the case of injection (e).